Evaluation of security features for new U.S. currency

Sara E. Church, Thomas A. Ferguson

United States Treasury Department
Bureau of Engraving & Printing
Washington DC

ABSTRACT

Features for use in the first new design of United States currency in more than 60 years were selected from a field of over 130 possibilities. To narrow the field, individual features were subjected to a variety of evaluation methods, ranging from subjective to rigorous physical to limited production testing. Comprehensive evaluations were carried out by an independent committee of experts through a Treasury contract with the National Research Council (NRC) as well as by the interagency New Currency Design (NCD) Task Force of technical experts from currency production, issuing, processing and enforcement authorities. Features were also rated for effectiveness, durability, feasibility, intelligibility, security, production and processing impact and compatibility with design requirements. Through successive levels of evaluation, the original field was narrowed to 35 for scale-up testing to a handful for production testing. Full production testing and implementation schedule determined the final mix of features included in the new design Series 1996 $100 note.

key words: counterfeit deterrence, evaluation, currency, banknote, security, security features

1. DEVELOPMENT PLAN

The U.S. government will soon issue a new series of currency with enhanced security against counterfeiting. The main focus in developing the enhancements for the new series was the overt protection of the currency against increasingly available high-quality color reprographic systems. The advent of this technology, especially office and personal color copiers, scanners and printers, has significantly elevated the vulnerability of U.S. currency to opportunistic counterfeiting.

Development of the new currency design has been carried out through the interagency Advanced Counterfeit Deterrence (ACD) Steering Committee, which comprises high-level executives from the Federal Reserve, the Treasury, the U.S. Secret Service (USSS) and the Bureau of Engraving and Printing (BEP). This committee in turn established a technical group of agency experts to evaluate, recommend and develop the security enhancements to be incorporated into the new design series. This group , the New Currency Design Task Force, began in 1990 to develop a plan to carry out this task. According to their charge, the sole purpose in redesigning U. S. currency would be to enhance its security against counterfeiting. The Task Force did not consider changes to the design for any other purpose.

The new currency design plan developed by the Task Force established several parallel programs, which were to provide the input for final recommendations:

- In-house (BEP) designers developed designs with enhanced portraits and improved layouts for accommodating a wider range of security features, both for visual and machine authentication.

- A study by the National Research Council (NRC) provided an independent assessment of current counterfeit deterrent features and potential future features.

- The BEP procured and tested samples, both in the laboratory and in limited press trials, where possible, to assess production, durability and other practical aspects of features under consideration.

- Currencies of other major countries were informally surveyed for overt security features.

The information from these sources was analyzed within the context of agreed-upon constraints. Unless extraordinary justification could be found to warrant changes, the current note size, existing features, colors and portrait subjects was to be maintained in the new

0-8194-2033-6/96/$6.00

designs. This would facilitate co-circulation of old and new notes and minimize cost impact on the general public, as well as provide continuity in the recognizability of U. S. currency. Designs and features would vary by denomination, as appropriate.

2. DESIGN PHILOSOPHY

The first goal of the Task Force was to develop a design philosophy. According to the resulting philosophy, detailed below, a layered approach to security would be used to provide a broad range of protection.

The basis of this philosophy is that there is no perfect "counterfeit-proof" design. Anything that the BEP can produce, someone else can duplicate or simulate. The goal of the Task Force in developing the new design is to combine several layers of protection which make it increasingly difficult for counterfeiters to duplicate and increasingly easy for legitimate users to authenticate. The Task Force has developed the following criteria to meet this goal.

2.1. Constants

During the conversion from old to new design currency, both designs must inevitably co-circulate. In addition, as much recognition continuity as possible should be retained. These factors impose certain constraints on design options such that a number of features will be maintained from the current design.

SIZE: There should be no changes in the size of currency; all denominations should remain the same size.

PORTRAITS: The individuals portrayed on currency should remain unchanged, i.e., Washington - $1, Lincoln - $5, etc.

COLOR: All denominations should be the same colors.

THREAD: The security thread currently used in U.S. currency should be retained. The effectiveness of the thread against office machine copying and traditional counterfeiting should continue in the next design.

2.2. Synergism

A secure design is based not on the addition of or reliance on a single "panacea" device but on the synergistic effect of a combination or series of devices and features.

2.3. Targeted Cash Users

Different types of cash users have different needs in authentication of their currency. Features should be targeted to assist specific groups of users in the rapid and accurate authentication of their currency.

GENERAL PUBLIC: Visible and/or tactile features are to be provided for the general public to use to authenticate their currency without the aid of any device.

THIRD PARTY MACHINES: The new design will incorporate some machine-detectable feature(s) for potential use by commercial cash accepting and processing equipment. According to current policy, the equipment designers would be responsible for detecting and characterizing these features for their proprietary use.

FEDERAL RESERVE BANKS (FRBS): The design must include extremely secure features for high-speed, highly reliable authentication for currency processed at FRBs.

2.4. Targeted Threats

The new design should have a combination of features and techniques designed to provide a broad band of protection against the full range of potential threats. Features should be included to assure protection against each of the targeted threats.

CONVENTIONAL COUNTERFEITERS: This group traditionally employs offset printing and photographic plate production to print currency. The equipment and skills employed by this group range from crude to highly sophisticated and the volumes of notes produced can be relatively high.

ADVANCED TECHNOLOGY: This threat to U.S. currency is from the continued advances in color reprography, including color copiers and computer printers and scanners. With this equipment, high quality reproductions of any document can be made by anyone, with minimal technical knowledge. The quality and availability of this equipment continues to increase, while the cost decreases, thereby increasing the threat. In contrast to conventional counterfeiting methods, relatively low volumes of notes can be produced by any one counterfeiter, but traceability by enforcement agencies is severely decreased by the nature of the equipment and its universal availability.

SOPHISTICATED DUPLICATION: This threat would involve a well-financed and sophisticated effort to exactly reproduce all aspects of U.S. currency using intaglio printing, engraved plates, and specially manufactured paper.

3. METHODOLOGY

The New Currency Design Task Force conducted a thorough analysis to provide the Steering Committee with an explicit menu of the most promising candidate features. This analysis included the following steps.

3.1. *Commerce Business Daily* solicitation

The BEP placed an announcement in the *Commerce Business Daily (CBD)* requesting the submittal of counterfeit deterrent ideas, techniques and features for United States currency. The *CBD* is the publication in which all government contract information is announced. The purpose of BEP's announcement was to solicit responses from both known and new sources of technology for deterring counterfeiting and to provide a mechanism for the purchase of test quantities of candidate features. As a result, 135 features were received from over 30 vendors. This solicitation is now updated yearly to continue the receipt and testing of new counterfeit deterrent features (Figure 1).

> **COUNTERFEIT DETERRENT FEATURES FOR UNITED STATES CURRENCY**
> **The Bureau of Engraving & Printing (BEP) is interested in testing new counterfeit deterrent features for incorporation in a new U. S. currency design. The BEP will survey and evaluate available features for effectiveness, durability, compatibility with prospective designs and compatibility with present currency production and processing. The Government will consider both overt (visible) and covert (machine-detectable) products, including but not limited to inks, paper additives and laminated features. Offerors seeking specifications should request the following: BEP Specification I:TCGB-1a Inks: Typographic, Cope Green and Black; I:ICWC-1a Ink: Intaglio, Cylinder Wipe Currency; P:D-1K Paper: Distinctive; P:DST-2d Paper: Distinctive, with Security Threads. The BEP requests that interested vendors submit cost information and preliminary samples for initial screening to the Bureau of Engraving & Printing, Attn: Office of Procurement, Room 708-A, 14th & C Streets, S. W., Washington, D. C. 20228. Larger quantities of acceptable samples will be procured as small purchases for first-level evaluation.**

Fig. 1. Text of the *CBD* request for submission of counterfeit deterrence features

3.2. Subjective Expert Evaluations

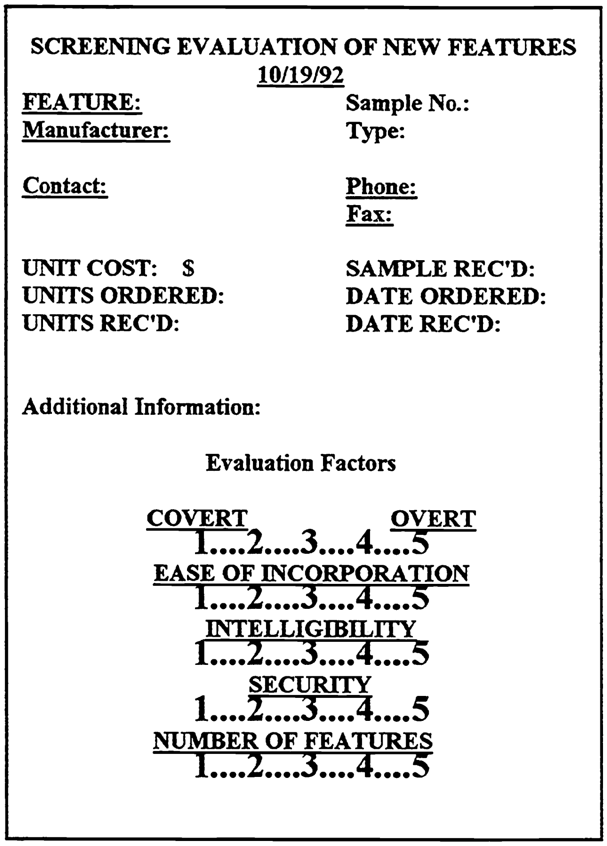
Each of the features received through the CBD program were subjectively evaluated by the technical experts on the NCD Task Force as well as a representative of the BEP currency design group. In these largely subjective evaluations, each feature was individually rated along a set of continuum characteristics plus a comment section for each feature (Figure 2). The characteristics evaluated were as follows:

Overtness: How easy is the feature to recognize without any technical devices? This rating category was used not to eliminate machine-detectable or covert features from consideration, but to focus attention on the intended function of the feature. The more overt the feature, the easier for the public to use for personal exchanges. For example, microlettering would rank somewhere in the middle because it requires a magnifier to verify.

Ease of incorporation: How easily can the feature be incorporated into the design and the production process? Rating of this factor is intended to take into account the presumed technical readiness, production factors and cost. A low rating would imply that the feature would require development to use, would have a serious impact on production or is expensive. A feature rated low in this category would not necessarily be eliminated from consideration, but its effectiveness as a security element would have to be considered carefully. For example, a hologram applied at BEP would rate low, but a hologram applied at the paper manufacturer would rate somewhat higher.

Intelligibility: How easily can the feature be explained to the general public? This rating is used to assess how obvious the feature is to use. Even if a feature is highly rated in all other categories, if its use requires very complex instructions or a high degree of skill to recognize, it may not be appropriate as an overt feature. This does not eliminate its potential use as a feature for forensic or expert identification. For example, a feature which looks green at a 90-degree angle, blue-green at 80, blue at 70 and purple at 68 would likely be too subtle for general use, but not for instrumental verification.

Security: How easy is the feature for someone else to obtain, simulate, duplicate or replicate? This factor gauges not only how well the feature can be compromised, but how easily the compromise can be recognized by the general public. For instance, a generic metallic ink might be obtained in the general market and difficult to distinguish from the genuine security ink but a color-shifting metallic ink would be much more difficult to obtain and easier to recognize as genuine.



SCREENING EVALUATION OF NEW FEATURES
10/19/92

FEATURE: **Sample No.:**
Manufacturer: **Type:**

Contact: **Phone:**
Fax:

UNIT COST: $ **SAMPLE REC'D:**
UNITS ORDERED: **DATE ORDERED:**
UNITS REC'D: **DATE REC'D:**

Additional Information:

Evaluation Factors

COVERT **OVERT**
1....2....3....4....5
EASE OF INCORPORATION
1....2....3....4....5
INTELLIGIBILITY
1....2....3....4....5
SECURITY
1....2....3....4....5
NUMBER OF FEATURES
1....2....3....4....5

Fig.**2**. Format for subjective expert evaluations of features for new currency

Number of properties: How many detection characteristics does the feature include? This is a numerical count of how many ways the feature can be recognized, whether visually or mechanically. For example, an embedded security thread (1) with graphics (2) and UV fluorescence (3) would be rated "3."

Each of these aspects of each feature were rated on a continuum from 1 (poorest) to 5 (best) and the results from all evaluations tabulated and averaged. Interestingly, the results were not always intuitive, but combined with the comments, they were useful in focusing attention on the ostensible merits and drawbacks of each feature. This level of evaluation was used to determine which features would be acquired in larger quantities to carry out further testing and analysis. About 35 of the original 135 features were selected for further study.

3.3. Industry Review

To determine the effectiveness and durability of security features already in use, the NCD Task Force surveyed the overt features in use in international currencies. This review provided a useful reference in the evaluation of candidate features for U.S. currency.

3.4. National Research Council (NRC) Study

The BEP contracted with the NRC National Materials Advisory Board (NMAB) to study the effectiveness of available counterfeit deterrence features in the context of United States currency. The NMAB therefore assembled a committee of experts to review the threats posed by current and developing technologies and to analyze the counterfeit deterrent methodologies available to thwart these threats. The NCD Task Force was represented at all of the Committee's working meetings and worked very closely with them. The study was completed and the final report[1] published in 1993. A follow-on study, completed early in 1995, addressed the recurring issue of features for the visually impaired or blind segment of the population[2]. The NMAB committee independently developed evaluation methods and criteria. The level of expertise and the independent nature of this evaluation process provided extremely valuable input for the total design effort. Many of the features recommended by this committee were adapted and incorporated into the new design.

3.5. Matrix Evaluation

The NCD Task Force developed a matrix system for the evaluation and rating of all potential candidate features. In this system, a separate matrix is used to evaluate each feature for various functional aspects, such as effectiveness at preventing counterfeiting, effectiveness as an authentication device for each target client, cost to produce and technical readiness. In addition to individual evaluation, features were rated for synergism in combinations with other features. An example of the structure of an evaluation matrix is shown in Table 1. This table shows the matrix for rating the effectiveness of various features in preventing various types of counterfeiting. The list of features shown is merely representative and can be tailored for specific cases. The matrix shows several rating options for each feature plus Score and Rate columns. For the Effectiveness evaluations, the options are Poor (P), Moderate (M) and Very (V). For other evaluations, the categories would be different; e.g. for Cost, they would be Low, Moderate and High. After a qualitative rating as to effectiveness has been assigned to a feature, the corresponding score (for instance, P=0, M=1, V=2) is used to calculate the numerical rate. The rate is expressed as the percentage of total possible points for a given category. The notes in Figure 3 give additional details on the evaluation matrix system.

EVALUATION MATRIX FOR COUNTERFEIT DETERRENCE FEATURES 1992-1993

1. Individual evaluations are weighted as follows to obtain scores in each category:

   EFFECTIVENESS
   Prevention, Detection: P(Poor)=0; M(Moderate)=1; V(Very)=2

   PRODUCTION FACTORS
   Technical Readiness: Short Term=2; Intermediate Term=1; Long Term=0

   Cost: Low=2; Moderate=1; High=0

2. Rates and Totals for individual and comprehensive categories are obtained by conversion of scores to percentages of highest possible scores in each category:

   EFFECTIVENESS Total 72
   Prevention: Casual, 12; Expert, 12; Advanced, 12; Total 36
   Detection: Public, 12; 3d Party, 12; FRS, 12; Total 36

   PRODUCTION FACTORS Total 24
   Technical Readiness: Total 12
   Cost: Total 12

3. Average Ratings in the Summary of Results are the averages of the Total Effectiveness, Technical Readiness and Relative Cost percentages equally weighted.

4. Group Averages in the Summary of Results are the average of the Average Rating values within a Feature grouping, excluding distribution descriptors (random, localized, distributed pattern, registered).

Table 3. Explanation of evaluation matrix system for features for new U.S. currency design

Table 4. Evaluation matrix for counterfeit deterrence features 1992-1993

EFFECTIVENESS: PREVENTION																
	Type of Counterfeiter															
	Casual					Expert					Advanced					
FEATURE	P	M	V	Score	Rate	P	M	V	Score	Rate	P	M	V	Score	Rate	TOTAL
FIBERS																
fluorescent/phosphorescent																
random																
localized																
PLANCHETTES																
iridescent																
fluorescent/phosphorescent																
random																
localized																
THREAD ENHANCEMENTS																
fluorescent/phosphorescent																
denomination by position																
OPTICALLY VARIABLE INK																
existing color pair																
custom color pair																
IMAGE REDESIGN																
portrait enlargement																
intaglio enhancement																
counter design changes																
interference patterns																
new layout																
OPTICALLY VARIABLE DEVICES																
holograms																
thin film devices																
diffraction gratings																

3.6 Miscellaneous Comments

Cost: The cost of producing U.S. notes currently in circulation is about 4 cents each. The projected production in fiscal year 1996 is 9.6 billion notes. If the cost for each of these were increased by 1 cent, the total cost for the fiscal year would increase by $96,000,000. The use of any individual new feature must therefore be well-justified if the cost is even fractions of a cent per note.

Durability: Any new feature added to a note must be as durable as the note itself and retain effectiveness during the entire lifetime of the note. However, different denominations will have different lifetimes, which may or may not be taken into account.

Availability: For incorporation into U.S. currency, the feature must be available from the manufacturer in a timely manner in sufficient quantities to support maximum production rates.

Manufacturability: The incorporation of a new feature must fit into the BEP's production system. Although the BEP can in theory produce anything that is technically feasible to produce, in reality such factors as lead times required for procurement of equipment, space and labor requirements and environmental regulations impose substantive constraints.

4. RESULTS

By the end of 1993, the major programs of the development plan were completed to the extent that recommendations for the new currency design could be made. The recommendations were based on the general findings of the studies and specific results of the evaluations, including both the independent studies by the NRC and the in-house studies at the BEP.

4.1. Findings

The studies conducted by the Task Force unexpectedly confirmed that there were no revolutionary devices or techniques available. Nearly all the techniques reviewed were iterations or improvements of previously existing or similar devices reviewed and analyzed during earlier study in the 1980's. They further supported the premise that no single perfect device exists that will prevent counterfeiting. Any device can be reproduced or simulated at some level, given sufficient time and resources. A combination of features aimed at various client audiences and types of counterfeiters ensures the greatest security for U.S. currency.

These findings influenced the Task Force's general approach to the studies and affected the way the results were presented.

4.2. Recommendations

The results of the various programs undertaken by the NCD Task Force were synthesized into a design concept to serve as the blueprint for the entire series of notes, which is eventually to include all denominations. The recommended concept was approved by Secretary of the Treasury Lloyd Bentsen on July 14, 1994, and announced to Congress and the general public that same day. Contrary to what many people believe, Congress does not have to approve the new design. Since 1862, the designs of the currency have been at the discretion of the Secretary of the Treasury[3]. As seen in the schematic representation used to illustrate the concept, Figure 4, the ten recommendations are general rather than specific: color-shifting ink, machine-detectable thread, etc. Details of the design and specific features would not be released until full-production testing could be carried out and successful implementation verified. This procedure avoids the necessity to revise the announced design as changes in response to test results are made.

Once the Secretary approved the design concept, testing and evaluation to determine specific details of individual features for use in the $100 notes began. The BEP began steps to manufacture printing plates and purchase specific materials in production quantities, both of which require long lead times, a year or more. During this phase, specifications for individual features would be developed and designed to be integrated into the overall concept. Aesthetic synergy of the note design and features and durability under production conditions would be evaluated at a number of specific stages. Some features would be eliminated during this phase for production or processing reasons.

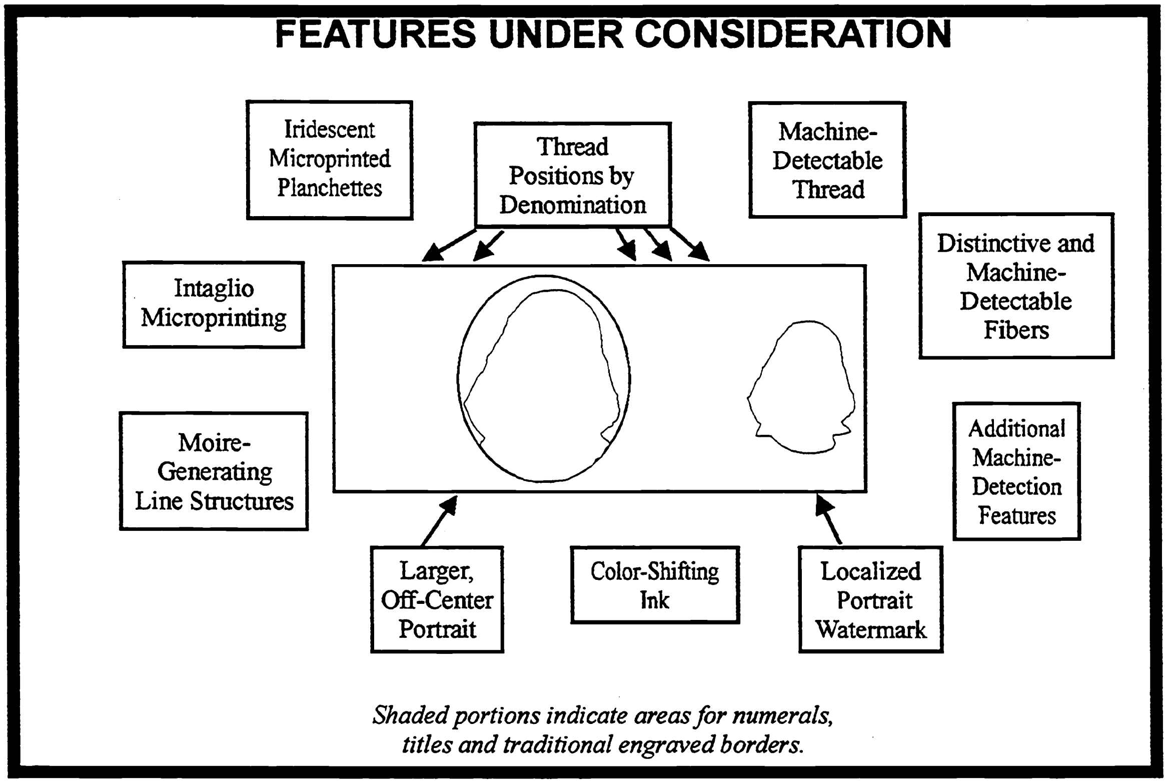

FEATURES UNDER CONSIDERATION
Iridescent Microprinted Planchettes
Thread Positions by Denomination
Machine-Detectable Thread
Distinctive and Machine-Detectable Fibers
Intaglio Microprinting
Moire-Generating Line Structures
Additional Machine-Detection Features
Larger, Off-Center Portrait
Color-Shifting Ink
Localized Portrait Watermark
Shaded portions indicate areas for numerals, titles and traditional engraved borders.

Figure 4. Schematic representation of new design concept announced July 14, 1994

5. SCALE-UP AND PRODUCTION TESTS

5.1. Proof tests

For the first tests during fall 1994, only a single-note die with the enlarged, off-set portrait of Benjamin Franklin was available, so the first tests were manually-generated die proofs. For this test, 1000 sheets of new currency design paper with four different watermark sizes and various threads were obtained. The resulting proofs were used to provide guidance in making preliminary decisions on watermark size, thread positions and other visual options for the next round of tests. Color-shifting ink options were limited at this point to violet-green, green-magenta or green-black.

An interesting result of this phase of the evaluation concerned the size of the watermark. Four watermark sizes were tested: (1.0", 1.1", 1.2' and 1.3" top of head to bottom of chin). Before the die proofs were actually printed, based only on transparent overlays of the design on the watermarks, most of the evaluators favored the larger watermark sizes. They felt the larger size would give higher recognition value and maximize production factors. However, after the die proofs had been printed, the tendency was toward the smallest (1" top to chin) version, which was ultimately used. This smaller size actually allowed for better centering in the design window, thus providing better recognition and more flexibility in position registration.

5.2. Load Tests

In March 1995, a full load of 20,000 sheets of new design paper with two watermark sizes and two thread styles was received from the manufacturer. Some of these sheets were printed using current design plates as a control; the remainder were printed using a single prototype set of new design plates. The purpose of this test was to address feeding and processing issues. Full durability testing was carried out on these sheets with satisfactory results. No serious problems were encountered during this phase. Problems had been expected in stacking and feeding the new paper due to the presence of the watermark and the difference in the machines used to make the new paper compared to the old threaded currency paper. This test was used to carry out bid tests for the color-shifting ink. Only the green-black passed all requirements. Final sheet layout was developed based on results from this test. Some issues regarding the flexibility in the dimensions of the gripper edge were resolved from this test. Some adjustments were also necessary in the engraved image to optimize printability of some of the new design elements, particularly the concentric fine lines and the color-shifting numeral. Modifications were also made to the numbering blocks on the overprinting equipment.

5.3. Process Tests

Originally, this 100,000 sheet test was scheduled for July 1995, still using the prototype plates. Since the final, production plates were almost finished, however, the test was delayed until early August, when 100,000 sheets of the new design paper were intaglio printed and a full process (100,000 notes) was overprinted and finished as notes. These tests went smoothly, except that excessive amounts of color-shifting ink were being consumed. Adjustments in the fountain settings alleviated this problem to some extent, but excessive use remains a problem. The sheet layout was finalized at this point.

5.4. Final Approval and Production

As soon as paper with the final watermark and thread layout was received, exemplars were made and presented to the Secretary of the Treasury for final approval of the new design. His approval gave BEP the authorization to begin full production of the new design $100 notes in mid September 1995. On September 27, the new design was formally announced in a press conference, with issuance to follow in the first part of 1996. The BEP has been printing the new design $100 notes continuously since the new design announcement. The new $100 notes will be issued in the first quarter of 1996. Lower denominations will be issued sequentially in descending order of value at approximately one-year intervals.

6. SUMMARY

Technical and design features for the new U.S. currency were determined through several levels and types of evaluation. The development process can be broken down into several levels: market survey, industry review, design development, technical evaluations and production tests. These levels of evaluation were used to establish and narrow the field of candidate features to feed into the successively more rigorous evaluation techniques. The types of evaluations used were subjective expert evaluations, matrix analysis, independent NRC studies and durability tests. The first tier of evaluations reduced the field of potential features for integration with a design concept used to carry out preliminary laboratory and limited production tests. The next round of evaluations reduced the field to ten general recommendations in a more specific design concept which was released to the public. The final phase of evaluations used modified and standard durability tests on production-scale products to verify feasibility for full-production implementation. This process further narrowed the number of new features which were ultimately incorporated into the new design $100 note announced in the fall of 1995, to be released in the first part of 1996.

7. REFERENCES

1. National Research Council (NRC). *Counterfeit Deterrent Features for the Next-Generation Currency Design*. National Materials Advisory Board. Washington DC: National Academy Press, 1993.

2. National Research Council (NRC). *Currency Features for Visually Impaired People*. National Materials Advisory Board. Washington DC: National Academy Press, 1995.

3. 31 U.S.C. 5115(a)(2). 1862.